



Laser remote sensing for wind energy

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Laser remote sensing for wind energy

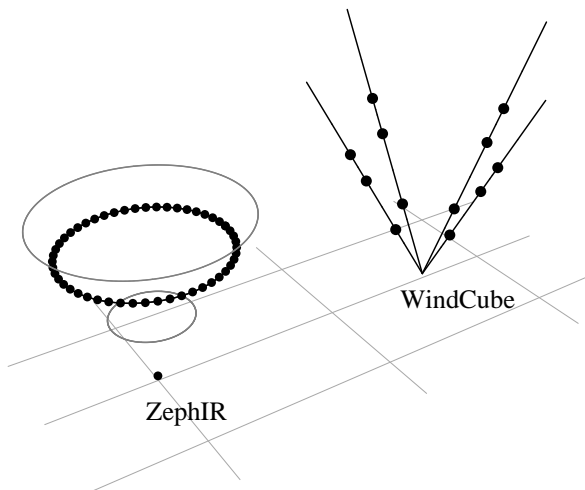
Jakob Mann

Wind Energy Division, Risø DTU, Roskilde, Denmark

May 2011 – EWEA Wind Resource Assessment Technology
Workshop, Brussels, Belgium

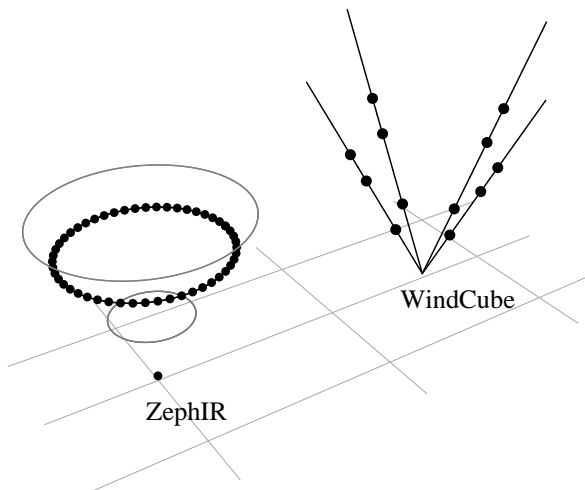
Doppler lidar instruments

continuous wave, pulsed



Doppler lidar instruments

continuous wave, **pulsed**



Some lidars for wind energy

Company	Instrument	properties and application
Natural Power	ZephIR300	RA, sea, control
Leosphere	WLS7, 70, 200	RA, meteorology, airports
Sgurr Energy	Galion	RA pulsed, flexible scan head
Catch the wind	Vindicator	yaw control, RA, 3 beam



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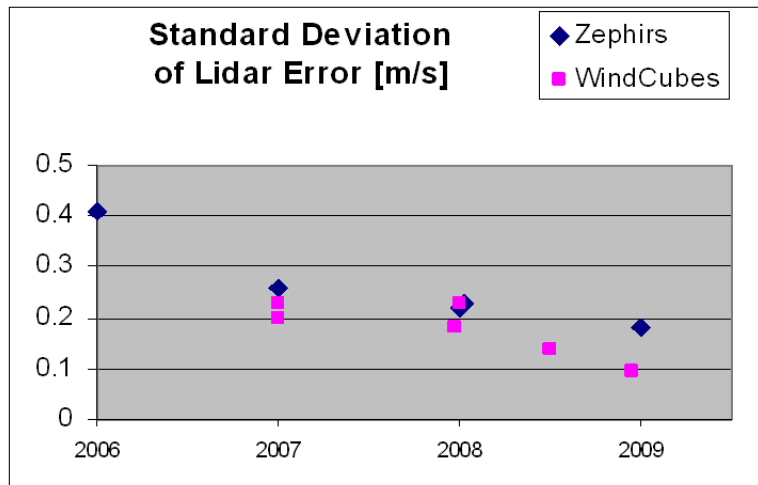
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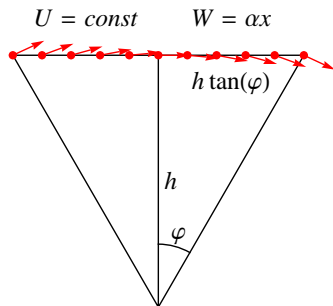
Mean wind speed measurements over flat terrain

ZephIR and WindCube

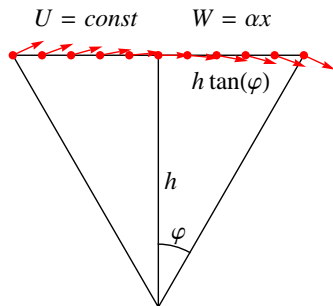


(Courtney *et al*, 2008 & 2011)

Conical scanning in non-homogeneous flow

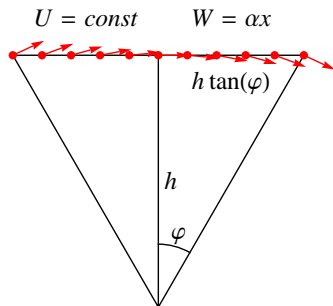


Conical scanning in non-homogeneous flow



$$\alpha = \frac{dW}{dx}$$

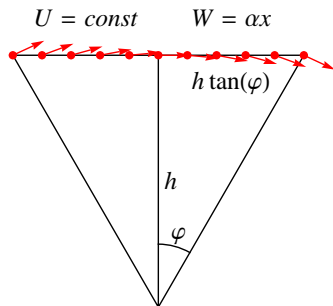
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$$\alpha = \frac{dW}{dx}$$

$$U_{lidar} = \frac{v_{down} - v_{up}}{2 \sin \varphi} = U + h\alpha$$

Conical scanning in non-homogeneous flow



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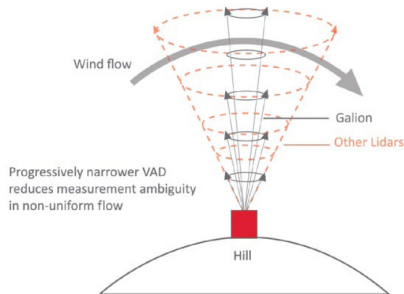
$$U_{\text{lidar}} = \frac{v_{\text{down}} - v_{\text{up}}}{2 \sin \varphi} = U + h\alpha$$

Does not depend on φ !

Smaller opening angle φ

A suggested solution

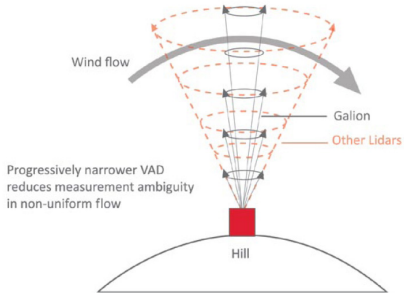
Ridge



Smaller opening angle φ

A suggested solution

Ridge

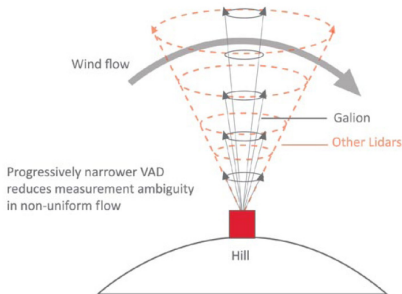


⚡ Should not work in theory

Smaller opening angle φ

A suggested solution

Ridge



⚡ Should not work in theory

⚡ Has not been demonstrated in practice

Mapping wind speed over complex terrain

Lockheed Martin Coherent Technologies and RES



VAD Technique Applied to Volumetric Long Range Data

- Collect radial velocity data over a large spatial region
- Scan in azimuth at a constant elevation angle --- a tilt
- Apply VAD algorithm to the annular sector and derive vector velocity estimate for center of sector
- Repeat for next overlapping sector
- Derive vertical profile from multiple tilts & ranges

Lidar

22 June 2009 - 14

⚡ Still systematic errors on wind components “perpendicular” to the beam

Other possible solutions

- Use flow models to calculate correction
 1. Bingöl et al 2009 *Met Zeit* (WAsP Engineering)
 2. Natural Power uses Ventos
 3. Leosphere uses Meteodyn

Other possible solutions

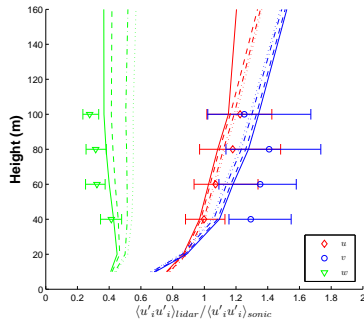
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- *Use three lidars!*

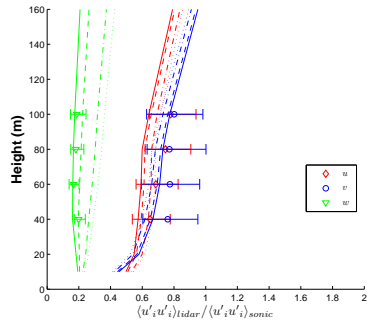
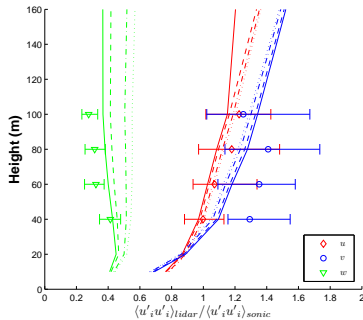
Turbulence measurements over flat terrain works less well

Systematic error under different atmospheric stability conditions; WindCube: Unstable and stable



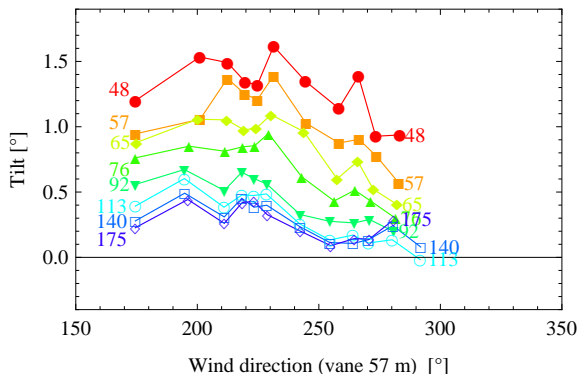
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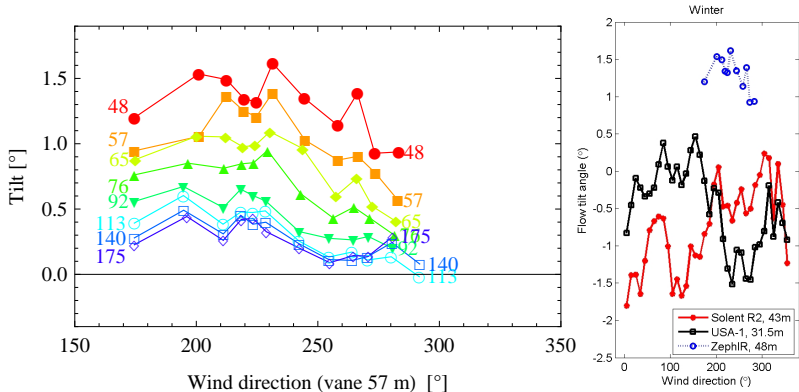
Measurement of flow angles over terrain

Small angles 400 m from a forest edge (Dellwik *et al Biogeosciences*, 2010)



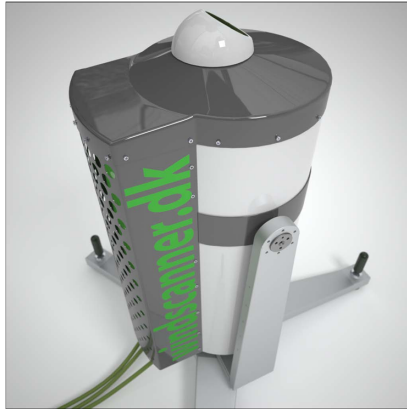
Measurement of flow angles over terrain

Small angles 400 m from a forest edge (Dellwik *et al Biogeosciences*, 2010)



Short range wind scanner

Combine three ZephIRs and move the beams fast





Long range wind scanner

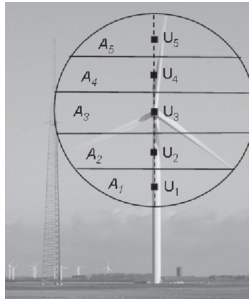
Combine three WindCubes WLS200 and move the beams relatively slowly





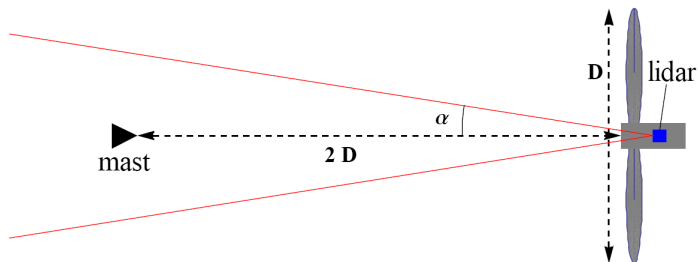
Power curves and control

- Power curves from profile measurements (IEC?)



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- Power curves from profile measurements (IEC?)
- Fast power curves from the nacelle



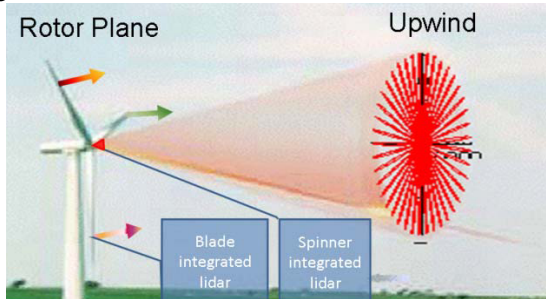
Power curves and control

- Power curves from profile measurements (IEC?)
- Better yaw control
- Fast power curves from the nacelle



Power curves and control

- Power curves from profile measurements (IEC?)
- Better yaw control
- Fast power curves from the nacelle
- Load reduction



Items to consider

- Wind lidars are very precise and suitable for resource estimation.
- Reliability is still an issue!
- There is a small bias on the wind speed measured by conically scanning lidars in complex terrain. Bias can be estimated.
- In contrast to mean wind speed, turbulence from lidars is biased even over flat terrain. We currently investigate ways to get more reliable turbulence estimates.
- Lidar technology opens new opportunities for wind turbine control, rapid power curve estimation, and research.

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